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Set-up of a decision support system to support sustainable development of the Laguna de Bay, Philippines

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Abstract

Over recent decades, population expansion, deforestation, land conversion, urbanisation, intense fisheries and industrialisation have produced massive changes in the Laguna de Bay catchment, Philippines. The resulting problems include rapid siltation of the lake, eutrophication, inputs of toxics, flooding problems and loss of biodiversity. Rational and systematic resolution of conflicting water use and water allocation interests is now urgently needed in order to ensure sustainable use of the water resources. With respect to the competing and conflicting pressures on the water resources, the Laguna Lake Development Authority (LLDA) needs to achieve comprehensive management and development of the area. In view of these problems and needs, the Government of the Netherlands was funding a two-year project entitled 'Sustainable Development of the Laguna de Bay Environment'.

A comprehensive tool has been developed to support decision-making at catchment level. This consists of an ArcView GIS-database linked to a state-of-the-art modelling suite, including hydrological and waste load models for the catchment area and a three-dimensional hydrodynamic and water quality model (Delft3D) linked to a habitat evaluation module for the lake. In addition, MS Office based tools to support a stakeholder analysis and financial and economic assessments have been developed. The project also focused on technical studies relating to dredging, drinking water supply and infrastructure works. These aimed to produce technically and economically feasible solutions to water quantity and quality problems. The paper also presents the findings of a study on the development of polder islands in the Laguna de Bay, addressing the water quantity and quality problems and focusing on the application of the decision support system.

Keywords: Sustainable development; Integrated water resources management; Decision support system

1. Introduction

With a total surface area of approximately 900 km^2, Laguna de Bay—Philippines, is one of the largest inland bodies of water in Southeast Asia. Some 100 streams drain into this shallow lake (average depth of 2.5 m) out of six different provinces and a total of more than 50 municipalities. The total area of the watershed is around 3820 km^2 and has been significantly modified by land use (deforestation, quarry activities, urban expansion). The Lake's only outlet controls the flow to the Pasig River that discharges into Manila Bay. During the dry season, the lake water level may fall to a minimum elevation of 10.5 m (corresponding to mean sea level), leading to the intrusion of seawater. With this flow reversal also highly polluted water from the Metro Manila area is carried to the lake.

Over the last decades population expansion, land conversion, urbanisation, industrialisation, operation of the Mangahan floodway and intense fisheries have led to significant changes in the Laguna de Bay catchment (Lee, 1997). Examples of observed changes are: increased siltation of the lake, the occurrence of eutrophication phenomena and bacterial pollution, significant loss of biodiversity, flooding problems and all sorts of secondary impacts on public health, standard of living, loss of recreational attraction, etc. (ERMP, 1993).

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Households contribute almost 70% to the total BOD_5 load into the Laguna de Bay (SDLBE, 2001), illegal garbage dumping is common and high loads of toxics enter the water system untreated. Available records of Laguna Lake Development Authority (LLDA) monitoring data, additional data sets on sediment quality and recent model simulations all demonstrate that the water quality and ecology of the Lake is indeed threatened by untreated and increasing domestic, industrial and agricultural pollution loads. It is now time for well-coordinated action to preserve this 'Living Lake' (a member of the Living Lakes Network) and to keep complying with the applicable user functions criteria (drinking water, recreation, fisheries, etc.).

In view of these changes, the Government of the Netherlands has been funding a two-year project entitled 'Sustainable Development of the Laguna de Bay Environment'. Activities have included work on establishing an Integrated Water Resources Management unit within LLDA to act as a knowledge centre dealing with the Laguna de Bay water system, its users and its management. The basic idea of creating the IWRM unit is to coordinate development of water, land, and related resources to maximise economic and social welfare, without compromising the sustainability of vital environmental systems.

The project aimed at updating all existing knowledge and data on Laguna de Bay and at developing a decision support system (DSS). The project, currently in its second year, focused on technical studies relating to dredging, drinking water supply and infrastructure works: all combined in one comprehensive capacity building case study. This case study aimed to transfer knowledge through on-the-job-training and to produce technically and economically viable solutions to water quantity and quality problems, which currently prevent the sustainable use of the lake.

2. The decision support system

The LLDA DSS (Fig. 1), integrates advanced software tools to provide an adequate scientific description of the Laguna de Bay water system (catchment and lake). The DSS will be an important tool to:

- increase the understanding of the relations between users and their water system;
- integrate research and monitoring efforts in scientific disciplines and translate the results to the LLDA management level;
- provide a common and user-friendly framework for the analysis and comparison of management options and measures.

The DSS includes among others the following tools: ArcView Gis (ESRI), Delft3D for hydrodynamics and water quality, hydrology and water quality database model HYMOS, waste load model WLM, ecological evaluation model DELGEM (all developed by WL | Delft Hydraulics), stakeholders analysis module, financial and economic analysis model (both based upon MS Office 2000 spreadsheet and database software).

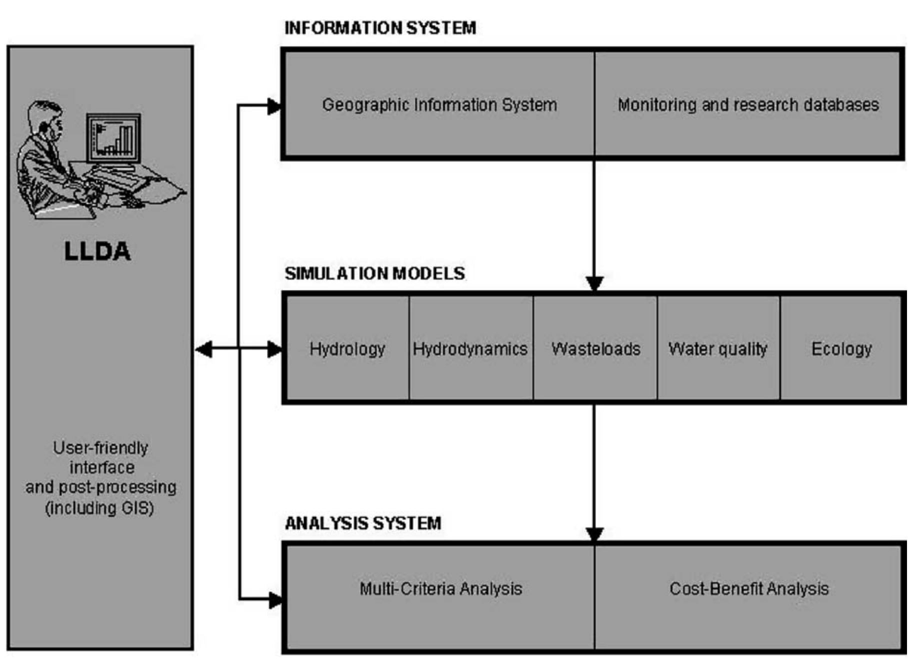

Fig. 1. LLDA Decision Support System.

The application of the DDS and the accompanying data collection and analysis studies has already led to an impressive update on many facts and figures such as physical characteristics of the Laguna de Bay catchment, total waste loads from the different sectors and areas, water and sediment balances, spatial and temporal compliance with applicable criteria, phytoplankton species competition, etc. These new data, insights and advanced DSS add to the credibility of LLDA as the knowledge institution regarding Laguna de Bay.

3. Capacity building case study: The Polder Island Development Plan

The SDLBE project, in its second year is focused on a capacity building case study: 'the Polder Island Development Plan' (PIDP; Fig. 2). The selected PIDP is a technical, economic and environmental study, including many different components. It aims to present a vision on sustainable development addressing the pressing problems and needs in the most populated, intensely used and polluted part of the Laguna de Bay catchment. It includes the creation of four polder islands (3000 ha) as an alternative to the more traditional land reclamation.

A polder is an area that is hydrologically separated from the surrounding area (through dikes), and of which the (ground) water can be controlled independently of the conditions of the surrounding area. In the proposed polders the water level outside the polders is higher than the maintained 'polder water level' (which is kept at a selected desired water level using pumping stations). The PIDP was limited to the pre-feasibility level.

Major activities within the capacity building case study included:

- study on soil conditions/geohazards;
- required dredging and civil engineering works;
- water supply and sanitation study;
- set-up of sanitary landfill;
- urban planning;
- shoreline restoration;
- integrated GIS—modelling assessment;
- initial environmental examination;
- stakeholders analysis;
- economic and financial analysis.

Related project activities included:

- study on improved environmental user fee system to address the pollution loads from the catchment;
- public awareness raising and education;
- legal and institutional setting for the new islands, and environmental law enforcement aspects;
- (technical) support to local governmental units and river basin councils;

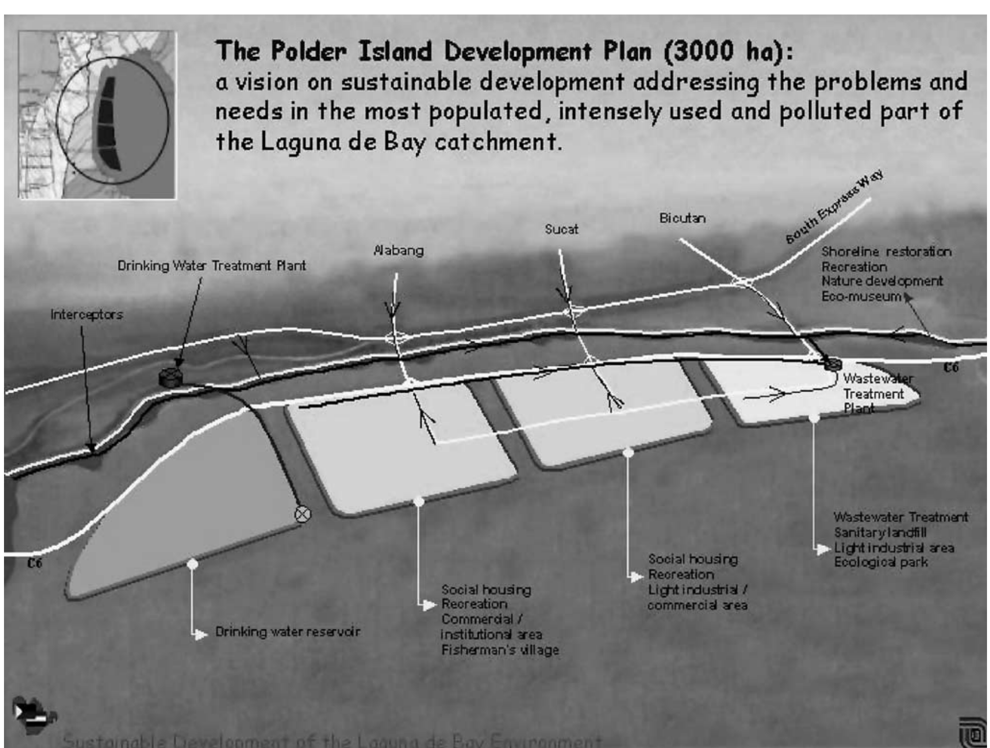

Fig. 2. The Polde Island Development Project (PIDP).

- alternative energy sources (e.g. wind and solar energy);
- alternative uses of dredged clay material.

3.1. Development of a drinking water reservoir within the lake (800 ha)

The most southern island is proposed to become a drinking water reservoir to provide a continuous 400 MLD water supply to address the expected inadequate reliable water supply by the year 2006. This will serve as interim for the proposed 'Agos River Multi-Purpose Water Resource Development' project. Afterwards, this polder could be converted into valuable land. In combination with operation of the major control structures in the Napindan River (Napindan Hydraulic Control Structures) the duration and level of increased salinities will be controlled (still allowing for the assumed beneficial effects of salinity intrusion on primary production and consequently fisheries). The reservoir and associated drinking water treatment plant is relatively easy to realize, overcomes problems related to conflicts of interests (fishery sector) and ideally connects to the existing distribution network.

3.2. Sanitary landfill (500 ha)

The north polder island can facilitate a new sanitary landfill for Metro Manila and nearby towns in this way, efficiently tackling the recent garbage crisis. In combination with improved garbage collection schemes, segregation and recycling it can solve the solid waste related problems for the next 52 years. The site will also serve as containment area for sludge, polluted sediments, industrial waste, temporal drying fields for dredged clay material and light industrial parks. Gradually the island will be converted into a recreational area (on top of the landfill). Advantages relate to: the thick layer of impermeable clay underneath the site, the size of the sanitary landfill island (500 ha), the accessibility and close distance to Metro Manila, the controllability of the leachate from the land fill due to a planned wastewater treatment plant, its offshore position (and low traffic impact and hinder to the surrounding area), the possibility to use the railway for transport to the island (including use of local transfer stations) and the availability of cover material within the project area (as a result of maintenance dredging).

3.3. Social housing (1700 ha)

By dedicating the new land of the inner two islands (1700 ha) for social housing congestion related problems in the dense adjacent coastal area can be reduced. These islands can provide space and job-opportunities to some 350,000 people. It is designed to include a commercial fisherman village, institutional and commercial parks, recreational area and sport complex and light industrial zones.

3.4. Interceptors and waste water treatment plant

To improve the water quality and ecology of the Laguna de Bay, collection and treatment of all domestic and industrial wastewater is proposed in the entire coastal area. The proposed treatment plant at the most northern polder island can also be used for the treatment of wastewater from the new polder islands and for treating the leachate from the landfill.

3.5. Construction of a new circumferential road 6 (C6)

To solve the congested Southern Express way and to mitigate the congestion in the adjacent municipalities the construction of the C6 (a six-lane highway which intersects four proposed interchanges) is proposed.

3.6. Dredging

The need for dredging the downstream part of the tributaries in the project area is twofold: the dredging of garbage and contaminated material attached to fine particles and dredging for maintaining the river outflow (flood control). The water system around the polder islands will be maintained at a certain depth to improve the water quality and allow for different user activities (fisheries, recreation, nature development, etc.). The dredged clay material can be used for raising the land elevation and as cover material for the landfill.

3.7. Shoreline development

To improve the natural and living conditions along the shoreline the following developments are proposed:

- fishponds for endemic species;
- green buffer zone;
- recreation activities along the shoreline;
- ecologic embankments;
- a Laguna de Bay eco-museum.

4. Use of the decision support system

As this paper focuses on the application of the DSS, the approach and some of the results are presented. The set-up (sequentially) of the various software tools followed the scheme depicted in Fig. 1 and ample time was included for the theoretical backgrounds and use of the software.

4.1. GIS and integrated modelling framework

The present performance of the various models is very promising thanks to the existing extensive datasets describing the Laguna de Bay. The present DSS should be considered as an integrated state-of-the-art set of tools scientifically describing the overall functioning of the Laguna de Bay water system in a unique way. For instance the coupling of all these disciplines (hydrology, hydrodynamics, waste loads, water quality, ecology and GIS) make the instrument very powerful in addressing all sorts of management problems (e.g. linking emissions

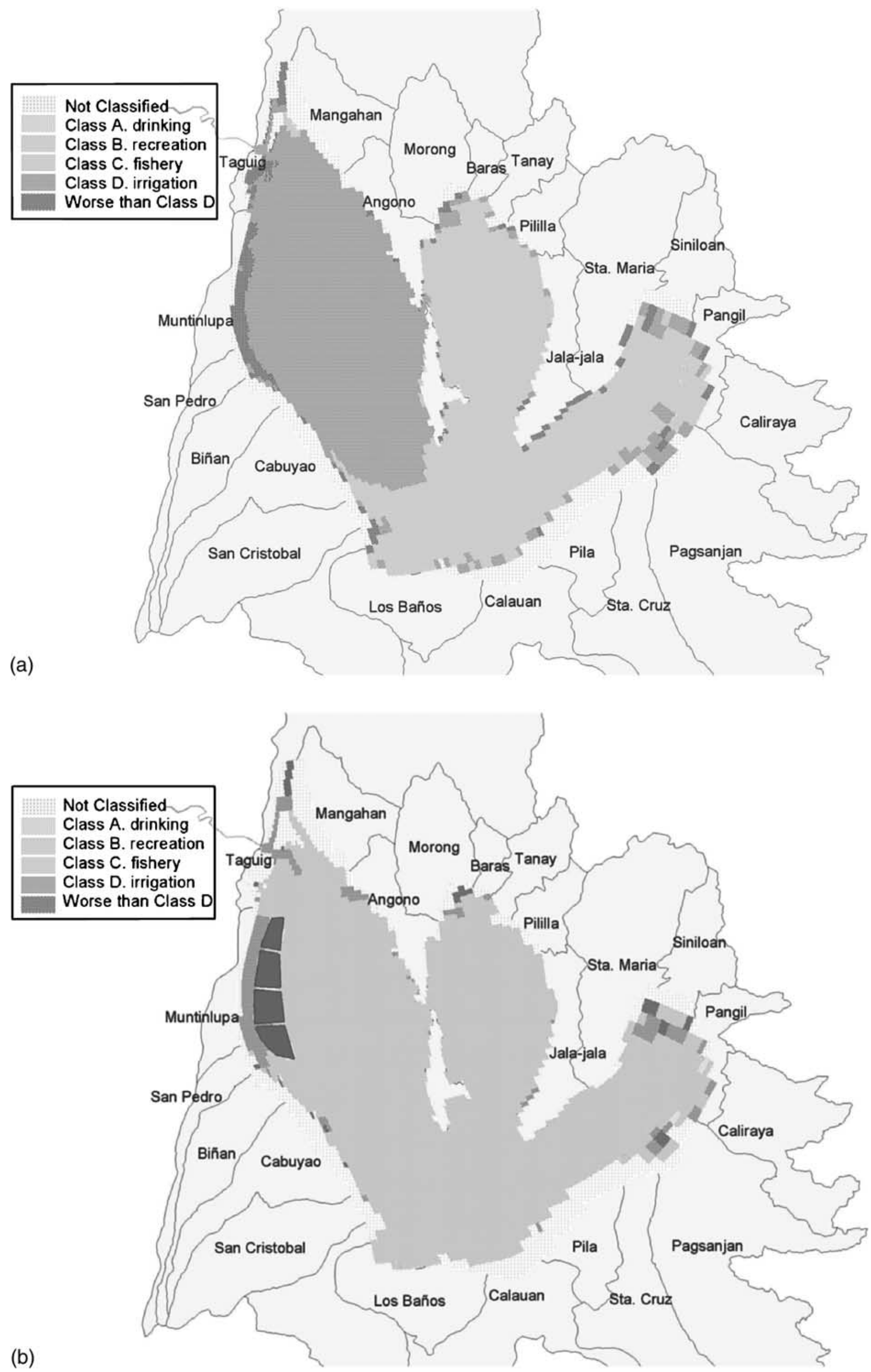

Fig. 3. (a) Autonomous development (10 years from present); model results show compliance with national (DENR) water quality criteria for the various water users and are based upon aggregated Delft3D model results. (b) Situation with polder islands (10 years from present); model results show compliance with national (DENR) water quality criteria for the various water users and are based upon aggregated Delft3D model results.

and developments in the catchment to downstream ecological effects), supporting planning activities and identifying new research needs (Fig. 3a and b). At the same time it should be realized that such a comprehensive instrument is very demanding, as it needs to be operated by many different and well-trained staff and should be subject to continuous calibration and validation efforts to avail of latest data and knowledge. As such, the performance and transfer of the tools is a direct reflection of the time, data and knowledge available. Hence, the moment new data comes in or new insights are gained, the calibration of the tools can be further improved or adaptations in the set-up of the tools can be made.

4.2. Stakeholders analysis

To learn on the social acceptability, to support project component prioritisation and to select most adequate project alternatives, there must be a balance between stakeholder priorities, technical and financial criteria and/or other requirements. Using a popular method for decision-making based upon a pair-wise comparison (Saaty, 1990), various indicators for decision-making could be made more transparent and comparable (effectiveness, cost-efficiency, etc.) and each view was represented.

The general approach is to have all stakeholders determine the relative priority (weights) of important independent 'criteria' (which are assumed to be related to possible LLDA projects). Hereto an inventory form was developed (in English and local language) and a straightforward software program was set-up.

The following steps were included:

1. Organise local workshops in all relevant municipalities and attended by all stakeholders (local governmental units, local communities, NGOs, farmers, fishermen and industrial representatives). In each municipality on average some 50 people were invited.
2. Determine the relative priority (weights) of important independent 'criteria', reflecting the personal views on issues in their area. The following (independent) sustainable development criteria for Laguna de Bay were used:
   - flood protection and erosion control,
   - reduction of water shortage,
   - congestion mitigation,
   - solid waste management,
   - public health quality,
   - peace and order,
   - improvement of standards of living/housing,
   - water quality and ecology improvement.
3. Present the capacity building case study (include pros and cons).
4. Collect feedback (positive vs. negative, concerns, recommendations, etc.).
5. Use the results to fine-tune the project components, determine alternatives or, for instance, to stop the project!

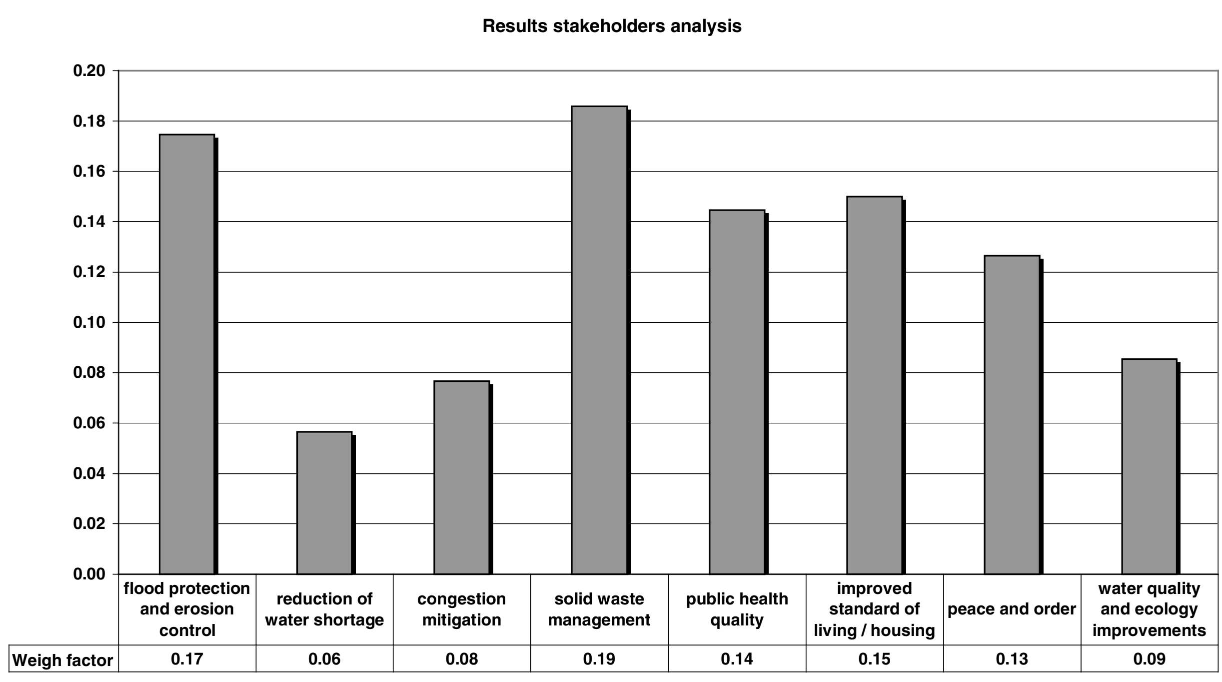

Fig. 4. Sector and area averaged result of the stakeholder analysis.

The results of the stakeholder analysis can be presented on different levels: per stakeholder, as average per sector from a specific municipality, average per sector for all municipalities, etc. (Fig. 4).

By integrating the (technical) efficiency with the costs, the social acceptability, the financial capability and the institutional capacity, recommendations could be made on the implementability of the project. However, even without the last ranking step (project component prioritisation) knowledge can be obtained regarding the specific interests of different stakeholders (collecting so-called personal blue-prints). As such, and in combination with an adequate questionnaire, information on the desirability of project/projects can be obtained in a more formalized and structured way.

The many workshops organized proved extremely useful as they:

- provided very valuable information on problems and issues in the area,
- gave an opportunity to present the new facts and figures and the development of the DSS, and could eliminate misunderstandings on technical issues,
- generated new project components and alternative lay-outs,
- provided an overview of all concerns regarding such a possible development and could be used to describe the social acceptability of the case study (as part of the initial environmental examination).

Table 1
Overview of economic viability for PIDP components

Project	IRR (Initial rate of return)	NPV (10%) (Net Present Value) (Million Pesos)	B/C (Benefit to cost ratio)	Economically viable
Drinking water supply	13%	1106	1.20	Yes
Solid waste management	29%	16 240	6.49	Yes
Wastewater treatment plant	15%	1768	1.45	Yes
High/medium density housing	32%	14 942	5.02	Yes
Medium/low density housing	27%	6189	2.52	Yes
C6 tollway	12%	216	1.20	Yes
Overall Project (6 components)	24%	41 393	3.04	Yes

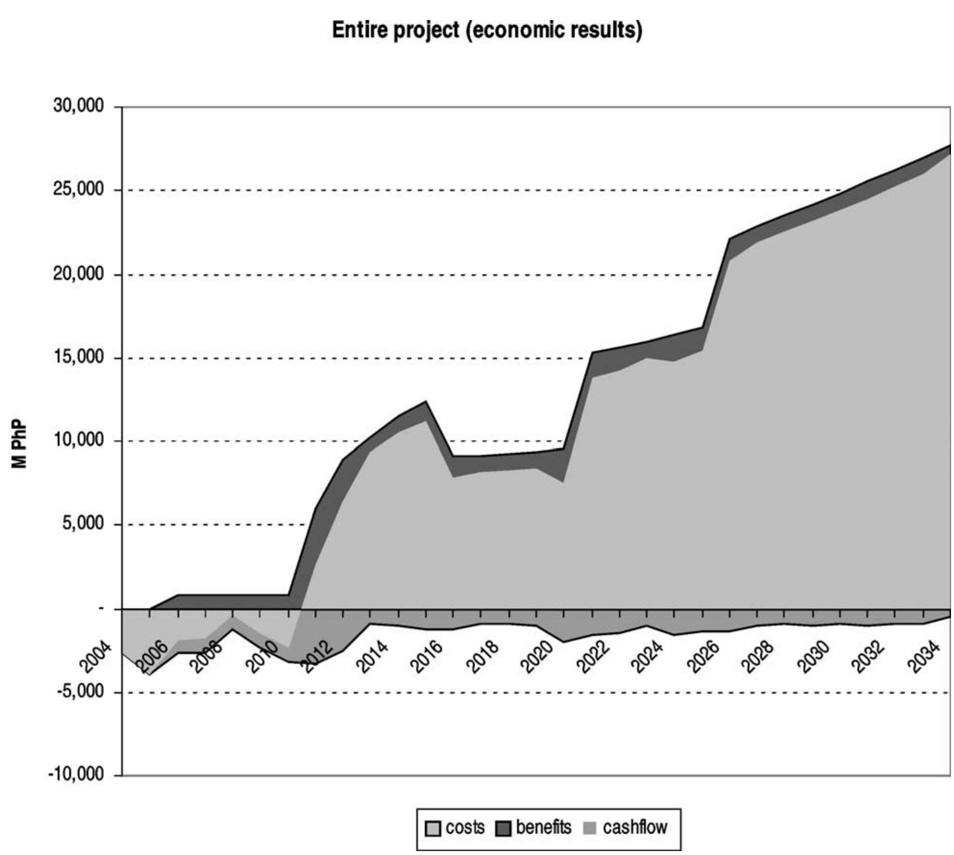

Fig. 5. Economic cashflow of Polder Island Development Plan.

4.3. Financial and economic analysis

The cost-benefit analysis (CBA) over time, making an assessment of the financial and economic viability of investments covered the development of four polders, each with a distinctive function.

The most northern polder will be used largely as a sanitary landfill for solid waste from the Metro Manila area, while on a small portion of the polder area a wastewater treatment plant will be constructed. In the CBA, the economic feasibility of these activities were evaluated, and the project cost covered development of the landfill and the construction of the waste water treatment plant. Project revenues are the foregone cost of more costly alternative solutions that achieve the same objectives.

The second polder will be used for social housing (high and medium density urban development). In the CBA the project costs of this polder includes, in addition to the investments made in dykes and a pumping station, land reclamation and site preparation costs: e.g. road network, power lines, street lighting and sanitation. The sale of the land to the government is the expected project revenue.

The third polder is also used for housing, but contrary to the second polder, it concerns middle-income housing (medium and low density housing). The project cost consists of the same items as for the second polder: dykes, pumping station, reclamation and preparation of the site. The sale of land to the public or to a project developer is the benefit coming from this polder.

The last polder will be used as a drinking water basin. The cost of the project cover dykes and a pumping station for the polder, a raw water pipeline to the mainland where a water treatment plant is projected. Also considered are clear water pipelines from the treatment plant. Project benefits, are considered to be the foregone cost of alternative and more costly solutions that achieve the same objective.

To be effective, also, large scale planning must have the "buy-in" and extensive support of most major stakeholder groups and this can only occur if there is shared vision of what people want (ERMP, 1993). In this respect the interplay with the stakeholders analysis was considered crucial.

The financial and economic analysis also covered the highway and the wastewater interceptors, making it all together a very demanding task. The software, as set-up, allowed for all sorts of sensitivity analysis and comes with user-friendly interface and different post-processing options (Table 1, Fig. 5). All project components turned out to be very viable with good opportunities for private participation.

5. Conclusions

This paper focused on the set-up and application of the DSS as a unique and integrated way of supporting the LLDA management in their planning, development and research tasks. The joint set-up of the DSS and analysis studies in combination with the very innovative and challenging capacity building case study has received very positive responses by the national leadership and local press, and the effective and stimulating transfer of knowledge has added significantly to the credibility of LLDA as the knowledge institution on Laguna de Bay.

As such, it is believed that the right project approach was adopted for the project. Rather than having a team of researchers and consultants setting up a DSS, doing a study and submitting a report, LLDA has been stimulated to do much of the work themselves and to feel responsible for it. This has added significantly to the capacities, knowledge and credibility of the organization and will prove extremely useful in addressing the development and implementation of a sound vision on sustainable development.

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